Науковий вісник Національного університету біоресурсів і природокористування України. Серія: техніка та енергетика АПК. 2018, Вип. 296, 89-94
ISSN 2222-8594 (print), ISSN 2415-7694 (online), www.journals.nubip.edu.ua/index.php/Tekhnica

DOI: 10.31548/machenergy.2018.02.089-094

UDC 681.511.4:664.1

ANALYSIS OF TECHNOLOGICAL PROCESS EFFICIENCY OF SUGAR BEET CULTIVATION BASED ON SIMULATION METHOD

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Article history: Received: March 2018. Received in the revised form: April 2018. Accepted: May 2018.
Bibl. 22, fig. 0, tabl. 0.

Abstract. The paper considers the technological process of sugar beets cultivation as a single object of modeling. The aim is to investigate the interrelation of separate technological operations and evaluate the technological efficiency of the beet cultivation. The study of technological processes based on the simulation allows us to investigate interconnections, to highlight technical and economic indicators, to evaluate the impact on profitability, to determine the directions of development and ways to improve the technical and technological basis of the beet production industry.

Key words: sugar beets, technological process, technical tool, simulation, pre-sowing tillage.

Introduction

Sugar beet is a highly productive plant that allows receiving high profits while using an integrated approach to the technology of its cultivation. Although specific successes are achieved in the sugar beet cultivation in Ukraine, the constant task is set to increase the yield of sugar beet further, to significantly reduce losses during cultivation and, especially, during harvesting, to improve the technological qualities of raw materials surrendering to the factories.

Given the natural and climatic differences in sugar beet cultivation areas in Ukraine and based on the experience of agrarian countries, the cultivation of sugar beet should develop with high technical and technological reliability. The main priorities for development are high productivity (working width, working speed, etc.), multifunctionality one unit of soil cultivation and sowing operations, inter-row loosening and fertilization, single-phase harvesting of tops and root crops, etc.).

Formulation of Problem

An essential aspect of the sugar beet cultivation technology is careful compliance with all regulatory requirements, namely: optimally-early and short deadlines; ensuring a required depth of seeding when placed on a sufficiently densified bed with a layer of lumps of loosened soil sprinkled; observance of set intervals between seeds. Essential prerequisites for the formation of highly productive crops are: determining the timing of sowing sugar beet, soil temperature, soil physical properties, i.e., the soil ability to crumble without sticking to the working organs of agricultural machines. Also, it is necessary to take into account the climatic differences between the zones (sufficient, insufficient and unstable moisture) in Ukraine.

The process of growing sugar beet is a complex process and includes several components. The main ones are:

– tillage (spring and pre-sowing);
– soil fertilizing;
– sowing and formation of optimum standing density;
– the fight against weeds, pests, and diseases;
– harvesting with the least losses.

The purpose of tillage for sugar beet is to create favorable conditions for their cultivation. It requires water-air and nutrient soil regimes. All measures are directed to the creation of an arable and transitional layer to structure optimal for the cultivation of sugar beets.

Tillage is in close correlation with the specific soil-climatic conditions of the sugar beet growing area. It is necessary to decide on the choice of the technology of the main and pre-sowing tillage, taking into account the soil specification and weather conditions, technical possibilities, and the timing of sowing. But at the same time, it's important to achieve optimal soil condition for seed germination, growth, and development of sugar beet seeds.

Modern soil tillage tools allow preparing the soil for sugar beet sowing in 1-2 passages. When the soil is mature physically, the field for sowing sugar beet can be prepared in one pass. This is an important element of energy saving and a prerequisite for high-quality sowing. The main mistakes during presowing tillage are early start of work on damp soil; an excessive number of working passes because of separate operations are not combined in one combine, the high working speed of aggregates, deep pre-sowing loosening. One more mistake is pre-sowing tillage is carried out at a small angle to the direction of sowing.

The perfection of the working tools of machines is an indisputable factor of influence on the level of the field seeds germination. Working tools of agricultural machines are designed to perform the technological processes of presowing soil cultivation qualitatively, seeding in the soil, depending on its mechanical composition, density, and humidity.

Based on the characteristics of sugar beet sowing mentioned above, it is necessary to find the optimal parameters of the working tools of cultivators and seeders. Improved working tools can facilitate the reception of uniformly distributed seeds in rows, full and synchronized shoots and, consequently, "starting" growth and development of plants, ultimately - to increase crop yields. Thus, it is reasonable a comprehensive study of the technological processes of sugar beet growing with the development of models.

Analysis of Recent Research Results

The technology of sugar beet cultivation includes such fundamental technological processes as early spring and autumn plowing, pre-sowing soil cultivation, sowing, growing, harvesting. As the analysis shows, the efficiency of these processes depends significantly on the agroclimatic conditions and the working tools of the machines, which ensure the execution of individual technological operations and constitute of a particular process. In this case, the decision-making is wholly based on previous experience and expert judgments [1, 2], technological operations are considered separately [3, 4], the parameters of the working tools are investigated experimentally under stringent constraints [5-7], the simulation is usually carried out with a large number of assumptions and is aimed at describing the physical processes on individual technological operations [8, 9].

The analysis of publications on the optimization of technological processes for the production of sugar beet leads to the formulation of the task of aggregate consideration of complex technological processes for sowing, growing, harvesting and processing of crops by mathematical models. In works [4, 10-14] separate technological processes are considered, and the choice of working tools of agricultural machines under difficult agroclimatic conditions is justified.

Research on the development and improvement of domestic technologies for growing and harvesting sugar beet are conducted in publications [6, 15]. The classification of harvesting machines and their working tools is carried out according to the conditions and methods of harvesting and given in [16, 17]. Experimental data and analytical dependencies of the technological process of pre-sowing tillage were obtained, the geometrical model of the working surface of a soil-working tool was proposed in [18]. Empirical regression models of the variation coefficient of stack placement were obtained depending on the speed of the sowing unit and the seed sowing rate in the seeding of the pneumatic and mechanical type, and production studies of seeders were conducted [19]. A mathematical model of the seed fall trajectory is presented in [20]. The basic principles of imitative statistical modeling of the technological process of sugar beet cultivation are developed and given in [21].

Among other cultivating field crops, sugar beets are most demanding in soil-climatic conditions, as well as in the working tools of machines which perform some complex technological processes for their cultivation and harvesting. Therefore, the production of sugar beet is determined by the level of intensive technologies used and the perfection of technical means at all stages from pre-sowing tillage and sowing of seeds in the spring until the beet harvesting in the autumn. The problem of choosing the most informative features of the technological process, developing system indicators and computational algorithm, taking into account the probabilistic nature of the operating conditions are poorly studied nowadays.

Purpose of Research

The work aims to develop a simulation model of the interrelation between the main technological processes of sugar beet cultivation to assess the effectiveness of the technology as a whole.

Results of Research

In this paper, the technological process of sugar beets cultivation as a single object of modeling is examined with the aim of investigating the interrelation of separate technological operations and evaluating the effectiveness of technological processes of sugar beet production.

Simulation modeling is a method of constructing a model of an existing or projected system and setting up experiments on a model. The components of the simulation model are the structure of the system, i.e., a set of element descriptions and connections between them; means of reproducing the behavior of the system. Such information as a whole has a logical-mathematical character and is represented in the form of algorithms set describing the dynamics of the system functioning.

The advantages of simulation modeling are that it is based on the methodology of system analysis. It allows carrying out studies of the projected or analyzed system according to the scheme of operational research. This scheme includes the following interrelated stages: a meaningful statement of the problem; development of a conceptual model; development and software implementation of the simulation model; checking the adequacy of the model and evaluating the accuracy of simulation results; planning experiments; making decisions. So, simulation modeling can be used as a universal approach for decision-making under uncertainty and for taking into account in the models of hard-to-formalize factors. Also, simulation modeling is applied the basic principles of the system approach in solving many application tasks, including the development of technical means and technological process of sugar beet production.

The technology of cultivation and harvesting of sugar beet includes some complex technological processes. For example, the preparation of the soil for sowing in the spring includes early springing and loosening of the plowland, which begins as soon as it becomes possible to enter the field, and the pre-sowing tillage is carried out immediately before sowing, and its beginning is determined by the degree of ripeness of the soil. Let's consider two main technological processes; they are pre-sowing soil cultivation and sowing. They largely determine the results of the entire technological chain.

Presowing tillage of the soil is carried out to a depth of 2-4 cm to destroy weeds and loosen the surface layer to create conditions for seed placement at the required depth and to produce even shoots.

Sowing with high-quality seeds in a well-treated soil at a given depth and regularly spaced distribution along a row in a favorable period ensures even shoots. Both processes are parts of the twin process.

Any technological process can be represented in the form of a multichannel multistage queuing system with repeated (reusable) service of requests. A large number of factors that need to be taken into account, the random nature of ongoing processes, as well as a large number of parameters and variables, makes it necessary to consider the technological process of sugar beet cultivation as a complex system. Analytical methods of queuing theory cannot be applied to such complex systems. Analytical methods of queuing theory are mainly limited to relatively simple single-channel and multichannel one-stage systems with steady-state service conditions and an exponential distribution of random variables. Thus, it is proposed to use means of directional simulation.

We now turn to the formalized description of technological processes as a complex queuing system, for which we distinguish two of its components:

1. The serviced system (SS_1) is a heterogeneous flow of service requests. Each type of request is characterized by its parameters. The initial parameters for each technological operation are regulatory requirements, agroclimatic conditions, and so on. As a result of the processing (simulation of the technological operation), the request a number of characteristics is assigned describing the effect obtained (values of evaluation criteria, application parameters for the next process operation).

2. A service system (SS_2) is a set of technical facilities that provide services for incoming requests. As is customary in the theory of queuing, technical means are called maintenance devices. Thus, SS_2 consists of some maintenance devices that are characterized by their parameters. As such devices, the working tools and agricultural machines available for performing certain technological operations are considered. Each device is characterized by its own set of parameters, the values of which are determined as a result of the experiment.

We introduce the structure-parametric spaces U and G, each point of these spaces determines, accordingly, SS_1 and SS_2. So, we can say that U is the destination space of the technological process, in which the structure and parameters of SS_1 are determined, and each of its points is characterized by the following main indicators:

- many types of the requests;
- parameters of the j-th type of the request.

By analogy, under the space G, we mean the functional purpose space of the technological process, in which the structure and parameters of SS_2 are determined, and the following main indicators characterize each of its points:

- a number of maintenance devices;
- parameters of the i-th device.

Let's assume that to each technological process there corresponds a partially ordered set $P(g,u,\Omega,\overline{x})$ of request motion routes, where Ω is the set of parameters describing interrelations of various types between separate elements. Partial ordering of routes is determined by the probabilistic parameters and the variables of the technological process. In the particular case, Ω is a square matrix, which consists of zeros and ones, and determines the relationship between the service devices. All units above the main diagonal determine the possibility of switching from the i-th device to the j-th, and below the main diagonal - in the opposite direction.

The vector $\overline{x} \in \overline{X}(g,u)$ consists of indicators that determine the discipline of service. $\overline{X}(g,u)$ is a variety of options for service disciplines, which are formed by an expert. In turn, each type of request corresponds to some partially ordered subset of routes $P_j \subseteq P(g,u,\Omega,\overline{x})$.

Let's assume that to each service device (element) gi or subsystem gl, there corresponds in U some given hypersurface $\Gamma_i(g^i,\overline{x},u)=0$. Partitioning into separate subsystems is carried out based on pre-adopted principles and indicators. Such principles are as following the functional purpose of individual SS_2 elements, the minimum effect of loading certain elements on others, and so on. Thus, we restrict the element (or subsystem) capacity:

$$\Gamma_i(g^i,\overline{x},u) \le 0,\ i \in M,\ \overline{x} \in \overline{X}(g,u) \tag{1}$$

In addition, we introduce the notion of hypersurfaces $\Gamma_k^*(g^i,\overline{x},u)=0, k \in S$ that are integrally defined by the capacity or other indices of all or a subset of subsystems SS_2. By analogy, they correspond to a set of S constraints

$$\Gamma_k^*(g^i,\overline{x},u)=0, k \in S,\ \overline{x} \in \overline{X}(g,u) \tag{2}$$

As a result, a specific parametric domain $D(g,\overline{x})$ with a parameter $\overline{x} \in \overline{X}(g,u)$ is defined in the space U. It characterizes the set of variants SS_1 that can be serviced by SS_2.

$$D(g,\overline{x}) = \begin{Bmatrix} u : \Gamma_i(g^i,\overline{x},u) \le 0, i \in M \\ \Gamma_k^*(g,\overline{x},u) \le 0, k \in S \end{Bmatrix} \tag{3}$$

SS_2 has the task to service the flow of requests based on the goals and objectives. Let's assume that such a goal is the vector V_o, which determines the planned indicators $\varphi_o^d = \{\varphi_{oj}^d\}$ and completely coincides with some value of $u \in U$, because in this case, the planned area consists of one point. The j-th component φ_o^d can be the mathematical expectation of a random variable that determines the receipt of the j-th type requests in the system or another indicator, which characterize the SS_1.

Let g_0 is the initial state of SS_2, and $D_0(g_0,\overline{x})$ is a part in U and

$$V^0 \in D_0(g_0,\overline{x}) \exists \overline{x} \in \overline{X}_0^0(g_0,V^0) \tag{4}$$

Let $\Pi(g_0,\overline{x},V^0)$ is the program that simulates the technological process. We assume that the numerical value of the function characterizes the functioning of technical means

$$F_0 = F_0(g_0,\overline{x},V^0) \tag{5}$$

In the case that condition (4) is not fulfilled, it is necessary to change the structure and parameters of SS_2. The function (5) is algorithmically defined and is determined by the simulation model of the technological process.

Let's consider the static formulation of the problem. It is necessary to determine the optimal composition (structure) g=(g0,δ) of technical means, the discipline of maintenance of the technological process.

All simulation models are models of the so-called black box type. This means that they provide the system's output if an input signal is given into interacting subsystems.

Playing samples by the Monte Carlo method [22] is the fundamental principle of modeling systems containing stochastic or probabilistic elements.

Conclusions

1. When managing various technological processes, it is necessary to provide in real time the calculation and optimization of the regime, which, given the stochastic changes in the parameters of the technological process, are belong to permissible modes. Therefore, we have to focus on the most unfavorable combination of factors of uncertainty and use the strategy of the guaranteed result. Until now, the problem of mathematical modeling of discrete, weakly structured processes and systems characterized by a set of criteria, stochasticity, interval or unclear values of the source data (such as the technological process and technical means of sugar beet production) is almost unexplored.
2. Taking into account the difficulties of conducting a real experiment, which is necessary for obtaining the values of the criteria, the use of simulation modeling is proposed. Simulation is a research method in which the studied system is replaced by the constructed model. The model with sufficient accuracy describes the actual system, and experiments with it are carried out with the aim of obtaining information about this system.
3. Investigation of the technological process based on the simulation by determining and justifying the optimal parameters allows us to define the technological variables, their relationships, and interconnections, to highlight technical and economic indicators, and to evaluate the impact on sugar beet yields.

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АНАЛІЗ ТЕХНОЛОГІЧНОЇ ЕФЕКТИВНОСТІ ПРОЦЕСУ ОБРОБІТКУ ЦУКРОВИХ БУРЯКІВ НА ОСНОВІ МЕТОДУ МОДЕЛЮВАННЯ

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Анотація. У статті розглядається технологічний процес вирощування цукрових буряків як єдиний об'єкт моделювання. Мета дослідження-вивчити взаємозв'язок окремих технологічних операцій і оцінки технологічної ефективності вирощування цукрових буряків. Вивчення технологічних процесів на основі імітаційного моделювання дозволяє досліджувати взаємозв'язки, виділити техніко-економічних показників, оцінити вплив на рентабельність, визначити напрямки розвитку та шляхи вдосконалення технічної і технологічної основи виробництва цукрових буряків.

Ключові слова: цукрові буряки, технологічний процес, технічні засоби, моделювання, передпосівної обробки грунту.

АНАЛИЗ ТЕХНОЛОГИЧЕСКОЙ ЭФФЕКТИВНОСТИ ПРОЦЕССА ВОЗДЕЛЫВАНИЯ САХАРНОЙ СВЕКЛЫ НА ОСНОВЕ МЕТОДА МОДЕЛИРОВАНИЯ

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Аннотация. В статье рассматривается технологический процесс выращивания сахарной свеклы как единый объект моделирования. Цель исследования-изучить взаимосвязь отдельных технологических операций и оценки технологической эффективности выращивания сахарной свеклы. Изучение технологических процессов на основе имитационного моделирования позволяет исследовать взаимосвязи, выделить технико-экономических показателей, оценить влияние на рентабельность, определить направления развития и пути совершенствования технической и технологической основы производства сахарной свеклы.

Ключевые слова: сахарная свекла, технологический процесс, технические средства, моделирование, предпосевной обработки почвы.